REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE** Technical Paper	**3. DATES COVERED** *(From - To)*
4. TITLE AND SUBTITLE		**5a. CONTRACT NUMBER**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		**5d. PROJECT NUMBER** 4847
		5e. TASK NUMBER 0249
		5f. WORK UNIT NUMBER 549871
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)		**8. PERFORMING ORGANIZATION REPORT**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048		**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S NUMBER(S)**

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20030128 090

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Leilani Richardson
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	A		**19b. TELEPHONE NUMBER** *(include area code)* (661) 275-5015

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

4847LJ22
48470249

MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO)

31 Oct 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-2001-217**
Wesley Hoffman (PRSM), "In Situ Processing Route for Uniform Density Carbon-Carbon Composites"

(Statement A)

Journal:
(Deadline: N/A)

In Situ Processing Route For Uniform Density Carbon-Carbon Composites

A recent development in composite processing at the Air Force Research Laboratory (AFRL) in Edwards CA drastically reduces both the cost of and processing time required for high performance carbon-carbon (C-C) composites. These composites possess a unique set of properties that make them ideal materials for high temperature structural uses, such as in rocket propulsion components, hypersonic vehicles, and aircraft brakes. C-C composites are stronger and stiffer than steel, while less dense than aluminum. In addition, they not only maintain their mechanical properties to temperatures in excess of 3000° C, the composite's material properties actually improve with heating as the non-ordered carbon is converted to the ordered graphite structure through the process of graphitization. In spite of their excellent properties, the use of carbon-carbon composites has been limited because of their high cost and oxidation at elevated temperatures.

For about thirty years, carbon-carbon composites have been manufactured principally by two processes, which differ in the means used to place the matrix between the fibers and thus "densify" the composite. One process involves infiltrating the composite preform with a hydrocarbon gas, while the other involves impregnating the fiber preform with a liquid hydrocarbon such as a pitch or resin. Both of these processes are followed by carbonization, which removes all non-carbon atoms and then by the graphitization process in which the partially densified composite is heated to temperatures in excess of 2400° C in order to enhance mechanical properties.

After the composite is graphitized, both current processes require that the outside of the partially densified composite be machined to remove material. This is necessary because both processes preferentially densify the outside of the composite and block the surface pores so that additional densification cannot occur. Because of this shortcoming, the infiltration/impregnation-carbonization-graphitization-machining cycle must be repeated a minimum of 3 times. Since each cycle requires 3-4 weeks, the densification process is very long and costly. By understanding the reasons for the shortcomings of current commercial processing, the In-Situ Rapid Densification Process, developed at the AFRL Propulsion Directorate, is able to avoid inhomogeneous densification and reduce the time required from many months to less than two weeks, with an associated dramatic decrease in cost.

AFRL's In-Situ Densification Process is an impregnation process that, in contrast to commercial processes, is able to rapidly densify the composite uniformly because it addresses the conflicting requirements of the impregnant's low viscosity and good wettability on the one hand and the need for a high char yield carbon precursor on the other. This is accomplished by using a low viscosity impregnant that wets the fiber perform surface in the first step of the process. This impregnant is sucked into the fiber preform like water into a sponge. This not only results in a uniform density, but, in addition, there is also no need for machining after densification to open up the surface pores. After the impregnant has filled the perform, in the second step of the process it is polymerized into a carbon matrix precursor that has a high carbon yield which means that fewer cycles are needed to bring the composite to final density. The carbon matrix precursor is then pyrolyzed to produce a high quality carbon matrix.

Not only does the In Situ Process produce a uniformly densified composite from any type of fiber perform (woven, braided, 1-D to n-D, felt, etc.) but, in contrast to other processes, there does not appear to be a size limitation. That is, performs with diameters up to 45 cm in diameter and lengths to 183 cm have been uniformly densified. In addition, another unique feature of this technology is

the ability to join carbon-carbon parts together with a seamless joint that possess significant mechanical strength.

Finally, it should be noted that, in contrast to other processes, it is not necessary to graphitize the composites which results in significant time and energy savings. Even without graphitization, the ablation and erosion performance of the In-Situ material equals that of commercial material when exposed to the exhaust of either liquid rocket engines or solid rocket motors. Thus, in most applications, it is not necessary to graphitize the material. However, when this material is exposed to graphitization temperatures in excess of 2200° C, a highly graphitic material with high thermal conductivity results. The significance of this result is that it is possible to use the low-cost liquid phase process to produce a C-C composite with the properties of a composite produced employing a gas-phase process. It is anticipated that the dramatic decrease in processing cost associated with this process will allow many new applications for this material to become a reality.

Opportunities:
The High Temperature Components Group welcomes inquiries from those interested in Cooperative Research and Development to utilize this process in the fabrication of their technology.

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